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Biological Evaluation of Melampsora rust disease of Arizona Willow (Salix arizonica Dorn.) on the Apache-Sitgreaves National Forest, Arizona.

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BIOLOGICAL EVALUATION OF *MELAMPSORA* RUST DISEASE OF ARIZONA WILLOW (*SALIX ARIZONICA* DORN.) ON THE APACHE-SITGREAVES NATIONAL FOREST, ARIZONA

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By

Mary Lou Fairweather

USDA Forest Service, Southwestern Region
State and Private Forestry and
Forest Pest Management
517 Gold Avenue, SW
Albuquerque, New Mexico 87102

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INTRODUCTION

During the summer and fall of 1992, I met with Tom Subirge, Soil Scientist, Apache-Sitgreaves National Forest, and Carl-Eric Granfelt, Volunteer Botanist, White Mountain Apache Tribe, to assess the incidence of Melampsora rust disease of Salix arizonica Dorn. (Arizona willow). Salix arizonica is a candidate for listing as a threatened and endangered species by the United States Fish and Wildlife Service. Two botanists had observed and remarked on Melampsora rust infection on S. arizonica in past surveys (Galeano-Popp 1988; Granfelt 1990). Clarence Dunbar and Greg Anderson, Forest Pest Management Biological Technicians, assisted me in surveying 9 of the 15 known S. arizonica sites on the Apache-Sitgreaves National Forest and two on the Fort Apache Indian Reservation (FAIR) in early September. The purpose of this evaluation is to report on the incidence and potential impacts of Melampsora rust disease as well as other insects and diseases of S. arizonica.

SURVEY

Salix arizonica site locations designated by Galeano-Popp (1988) for the Apache-Sitgreaves National Forest were used in this survey (Figure 1). Sites 3, 7, 8, 9, 10, 11, 12, 13, and 15 and Areas A and B on the FAIR were surveyed by walking the creek and examining S. arizonica and other willow species for signs of insect and disease activity. Grazing and elk rubbing were also included. Site characteristics and detailed information on S. arizonica plants within each site location are given by Galeano-Popp (1988).

OBSERVATIONS

Melampsora rust disease was observed in Sites A, B, 3, 7, 10, and 11, occurring on some S. arizonica, S. monticola, S. bebbiana, S. boothii, and rarely on S. geyeriana and S. scouleriana. Infection levels on infected plants were generally light to moderate, however, susceptibility varied both among species and plants of the same species. Salix arizonica and S. monticola were more susceptible, having heavier infestations (more uredia) compared to neighboring infected plants of other species.

Only three of the sites had individual S. arizonica plants which were heavily infected with Melampsora rust. These were found in Sites A and B on the FAIR and Site 3 on the Forest. Sites A and B are located along the same tributary of Snake Creek. The plants are typically less than a meter in height. In the fall of 1988, Granfelt observed dieback following heavy rust infestation, he described the plants as having a "burnt" appearance. The following year dieback of stems continued. While some of the plants resprouted others were completely killed. During this survey, there were moderately to heavily rust infected S. arizonica and the previous dieback was still evident, however, there were no signs of current dieback or mortality. Salix monticola was also moderately to heavily infected, but there were no signs of previous dieback.

Site 3 is along the West Fork of the Little Colorado in the Mount Baldy Wilderness. This area has the largest population of S. arizonica (363 plants). There were a few S. arizonica plants with light rust infection, and one large-sprawling plant with heavy infection. Some rust infected stems were over 5 feet in height. In some areas, this plant unit had dieback similar to that observed on the Reservation, however, sprouting was prolific and there were no areas of plant mortality. In addition, there were signs of dieback (dead stems) in species other than Arizona willow, some of which were associated with grazing damage.

Other impacts on S. arizonica include ungulate browsing and defoliation by the caterpillar of the mourningcloak butterfly, Nymphalys antiopa Linnaeus. Although not all plant units were browsed, there were signs of ungulate browsing in all areas surveyed. The tallest S. arizonica plants were attached to exposed rocks in the creek and protected by other willows and the creek from animal browsing.

Caterpillar feeding on S. arizonica, attributed to that of the morning cloak butterfly, was observed in Sites 3, 8, 9, and 10. Defoliation was generally light, however, in a few plants defoliation was heavy enough to cause branch dieback.

Tar spot disease was also observed on various willow species in Sites 3, 7, and 10. Similar to Melampsora rust, susceptibility varied between neighboring plants. Tar spot is a disease caused by the fungus Rhytisma salicinum. Tar spots are among the most showy and least damaging foliar diseases (Sinclair et. al. 1987).

Leaf spotting and stem cankering caused by unknown fungi or bacteria were also observed. Incidence was not abundant.

TECHNICAL INFORMATION

Melampsora Rust of Willows: M. epitea complex of races

Rust diseases are caused by fungi belonging to the order Uredinales, in the class Basidiomycetes. These fungi are all obligate parasites of vascular plants. They are characterized by a complicated life cycle involving up to five spore stages and, for many, requiring two systematically unrelated host plants to complete their life cycle. The latter are called heteroecious rusts.

The five spore stages of the rust fungi are:

- 0 **spermatia:** monokaryotic gametes.
- I **aeciospore:** nonrepeating vegetative spores usually produced as the result of dikaryotization. They germinate to initiate dikaryotic mycelium, and thus usually associated with spermogonia. In heteroecious rusts, aeciospores initiate infection on the "Main Hosts".
- II **urediospore:** repeating vegetative spores, usually produced on dikaryotic mycelium.
- III **teliospore:** produce basidia.
- IV **basidiospore:** monokaryotic spores produced on basidia, usually the result of meiosis. In heteroecious rusts, basidiospores infect the "alternate host".

The rusts on Salix spp. all belong to the genus Melampsora Castagne. With the exception of M. amygdalinae, all willow rusts are macrocyclic (produce all five spore stages) and heteroecious, their alternate hosts being members of the Pinaceae, Liliaceae, Amaryllidaceae, Orchidaceae, or members of three genera of the dicotelydons (Ribes, Saxifraga, or Euonymus) (Sinclair et. al. 1987). Ziller (1974) recognized the following species of Melampsora based on the alternate hosts: M. abieti-capraearum on firs; M. artica on saxifrage; M. epitea f. sp. tsugae on hemlock; M. paradoxa on larch; and M. ribesii-purpeae alternating on ribes (Ziller 1974). However, the complex of all North American willow rusts have been included in one collective species, Melampsora epitea Thuem. because they are indistinguishable from each other in their uredinial and telial states occurring on willow (Jorstad 1940; Yohem et. al. 1985; Savile 1973). Helfer (1992) reports 14 species of willow rust in Britain, based on spore and sorus characters. He particularly keyed in on the density of urediniospore ornaments.

All species have a similar life cycle. In spring, basidiospores from telia in dead willow leaves on the ground infect the alternate host (eg. ribes). Spermatia followed by aeciospores develop in approximately 2 weeks. The orange-yellow aeciospores, produced in chains, are dispersed by wind and infect willow leaves. Golden yellow uredinia appear on both sides of yellow leaf spots in about two more weeks. Their numbers increase throughout the summer during humid or wet weather as urediniospores reinfect willow. When rust is severe, leaves become completely yellow with uredinia and spores. Rust covering half or more of the leaf surface causes leaves to shrivel and fall. In late summer through early fall, brown, crust-like telia form in place of uredinia, and the surrounding leaf tissue dies, so that irregular gray-brown lesions form. Telia arise beneath the epidermis and overwinter in fallen willow leaves. In spring, they produce basidiospores, thus completing the cycle.

Willow rusts have shown a remarkable adaptation to short-season habitats, which further complicates distinguishing species on the willow (Savile 1953 and 1973). In many species, the uredinia produced following infection by aeciospores are capable of forming an overwintering mycelium in the embryonic leaves or catkins. The mycelium grows with the bud tissues in the spring and produces large or multiple uredinia early enough in the season to permit the production of secondary uredinia and then telia (Savile 1973).

The hyphae of rust fungi penetrate between the cells of the host and derive nutrients. Similar to mycorrhizal fungi, rust fungi, have adapted themselves to elicit a minimal host chemical defense response which they can tolerate (Manion 1991). While other organisms are held in check by the host chemical defense response, rust fungi avoid interference and competition for nutrients. The primary effect of Melampsora rust infection is premature leafdrop with accompanying loss of vigor. The early loss of leaves likely reduces carbohydrate reserves in tree roots, needed for early growth the following spring. Although early defoliation has been associated with some growth loss for aspen and cottonwood, the normal growth rate is so high in these species that growth loss is considered negligible (Sinclair et. al. 1987; Pinon 1992). A bigger impact from extensive Melampsora infection may be that it prevents willow shoots from entering dormancy in time, thereby causing subsequent frost damage (Verwigst 1990).

Host resistance to rust disease is genetically controlled between species and clones within species. In a natural condition in which a rust has evolved with two hosts, both the hosts and pathogen undergo numerous mutations and gene combinations for improvement of resistance or virulence (Manion 1991). Neither the hosts nor pathogen gain a strong advantage over the other for any length of time, a mutual tolerance develops. This mutual tolerance does not exist when a pathogen is introduced into an area in which a host species has not been able to develop mechanisms of resistance (Manion 1991). For example, white pine blister rust was introduced into North America from Europe in the late 1900s, within 50 years the rust severely reduced populations of various species of white pine throughout the northern United States and southern Canada (Manion 1991). More recently, it was discovered in the Sacremento Mountains in southern New Mexico where it is impacting the southwestern white pine (Hawksworth and Conklin 1990).

Mutual tolerance in co-evolved species can be disrupted under artificial conditions, as for example, when a host species is grown as a monoclonal crop of fast growing trees (Pinon 1992; Manion 1991). The narrowing of genetic variability in relation to disease resistance places a selection pressure on the pathogen population for a mutant or gene combination with the capacity to overcome resistance (Manion 1991). In a "natural" forest condition, Melampsora rust has not been considered a problem warranting control (Pinon 1992). However, with the threat of fuel oil shortages in the 1970s monoclonal crops of willow and poplar were planted for use as an alternative energy source, creating epidemic outbreaks of Melampsora rust infestations (Verwijst 1990; McCracken and Dawson 1992; Pinon 1992). The primary means of control in these forestry plantations is a genetic resistance program (Manion 1990; Sinclair et. al. 1987). These programs concentrate on breeding for a multitude of resistance factors, instead of a single gene-for-gene factor which the fungus can overcome by developing a new "race" able to conquer the resistance of the host (Manion 1991; Verwijst 1990).

CONCLUSIONS AND RECOMMENDATIONS

Due to the high level of rainfall that fell throughout the spring, summer, and fall of 1992, various species of Melampsora rust occurred at elevated levels throughout the Forest. For example, a Melampsora rust caused early defoliation of coyote willow in lower elevation riparian areas, while another species caused defoliation of susceptible aspen clones in higher elevation mixed-conifer forests. Therefore, it was considered a good year for assessing impacts of Melampsora rust disease to S. arizonica.

Unfortunately, the spore stages of Melampsora which occur on willow are indistinguishable with miscroscopic analysis, and identifying to species level involves cross-inoculation experiments. For now, the species of Melampsora infecting S. arizonica will be called M. epitea (Yohem et. al. 1985). M. epitea represents a complex of all North American willow rust species, each having specific alternate hosts (see Technical Information section). Possible alternate hosts for the rust which infects S. arizonica include species of ribes, fir, or saxifrage.

Rust infected ribes were observed near S. arizonica plants in the spring of 1992. Aecia are produced in the spring, so it may have been the aecial stage of another willow rust, M. ribesii-purpeae, on the ribes. However, ribes can also be the alternate host of Puccinia caricina (who's main host is Carex spp). Neither Melampsora or Puccinia have been previously described on ribes in Arizona (Yohem et. al. 1985).

Relative to other willow species in its habitat, S. arizonica and S. monticola share the position of being most susceptible to rust infection. However, S. arizonica may be more affected by Melampsora rust. Granfelt (1990) reported that both species were heavily infected in Site A on the Reservation in 1988, but only S. arizonica suffered dieback and mortality. Variability to a rust among host species and clones within species is well known (Pinon 1992; McCracken and Dawson 1992). However, it is also possible that the rust infection in S. arizonica made the plants more susceptible to a secondary pathogen or an environmental stress. Water had been diverted from the tributary of Snake Creek starting in the late 1970s, which is upstream from Site A. It is not known if this diversion created a stress to S. arizonica plants.

With the exception of Site A on the Reservation, infection levels in individual plants in 1992 were usually moderate, with few heavily infected plant units. Early defoliation was evident in the more severely infected plants, however, the only dieback and mortality observed during the survey was from previous years. Dieback in plants in Site 3 had occurred prior to 1988 (Galeano-Popp 1988), but dieback and mortality reported in Site A on the Reservation had occurred in 1988 (Granfelt 1990). Dieback was associated with clones which were very susceptible to rust infection. The rust infection may have subjected the plants to frost damage, however, this theory could not be confirmed with weather data from nearby Burro Mountain.

Since an indirect relationship between susceptibility of S. arizonica to Melampsora rust infection and dieback (and mortality) seems apparent, a recovery plan for S. arizonica should include practices which limit the incidence and impact of M. epitea. This does not mean that M. epitea is solely responsible for the demise of S. arizonica, but should be included in a list of impacts along with loss of habitat, grazing, and changes upstream.

The ability of a host to resist rust infection is genetically controlled (Manion 1991; Sinclair et. al. 1987; Pinon 1992). The populations of Arizona willow at each site (except Site 3) are extremely low and flower and seed production is practically non-existent. These two factors may indicate a loss of genetic diversity. Meanwhile the rust population is probably uninhibited and able to undergo genetic recombination every year. The narrowing of genetic variability in relation to disease resistance has been shown to place a selection pressure on a pathogen population for a mutant or gene combination with the capacity to overcome resistance (Manion 1991; Burdon 1991). More studies are necessary to ascertain the genetic diversity of the host in relation to rust resistance and what can be expected in the future.

During this survey, there was no apparent relationship between the size of an S. arizonica population and the amount or severity of rust infection. Nonetheless, maintaining and improving genetic diversity is an essential goal to include in the S. arizonica recovery plan. Vegetative reproduction from the present genetic pool may maintain the present level of diversity, however, sexual reproduction is needed to increase diversity and form a healthy population which is more resistant to S. arizonica as well as other insects and diseases.

Grazing was the most noticeable impact on flowering, especially in Site 3 where protected plants were producing seed. M. epitea may have an indirect affect on sexual reproduction by subjecting infected plants to frost damage and subsequent dieback (Verwijst 1990). Early defoliation caused by rust infection may also have an effect on flowering. However, past research on the allocation of resources between growth and reproduction has been inconclusive (Fox and Stevens 1992), and research with S. arizonica and related willows is necessary.

In 1993, I will continue surveying S. arizonica for Melampsora rust infection as well as other diseases. The willows will be surveyed in the spring for uredia. The uredia would indicate that the fungus overwintered in the host and an alternate host is not necessary for spread and survival. Willows will also be surveyed in the fall, similar to 1992 survey. In the spring the aeciospores on the ribes will be identified to the genus level to tell if it is a Puccinia or a Melampsora. This may indicate whether ribes is an alternate host for M. epitea, however, conclusive proof can only be derived through controlled inoculations. Subalpine firs and saxafrage in the surrounding area will also be examined for rust infection in the spring. I will also try to isolate the organism (fungi or bacteria) which makes a black canker and girdles the stems of S. arizonica, and determine its occurrence.

REFERENCES

Burdon, J.J. 1991. Fungal Pathogens as Selective Forces in Plant Populations and Communities. Australian Journal of Ecology 16: 423-432.

Fox, J.F., and G.C. Stevens. 1992. Costs of Reproduction in a Willow: Experimetal Responses vs. Natural Variation. Ecology. 72(3): 1013-1023.

Galeano-Popp, R. 1988. Salix arizonica Dorn. on the Apache-Sitgreaves National Forest: Inventory and Habitat Study. USDA Forest Service, Apache-Sitgreaves National Forests. 50 p.

Granfelt, C.E. 1990. Melampsora Infestation of an Arizona Willow (Salix arizonica Dorn.) Population. Unpublished Data. 9 p.

Hawksworth, F. and D. Conklin. 1990. White Pine Blister Rust in New Mexico. In Proceedings of the Thirty-eight Annual Western International Forest Disease Work Conference, Redding California. 157 p.

Helfer, S. 1992. The Rust Diseases of Willows in Britain. In Proceedings of the Royal Society of Edinburgh. 98B: 119-134.

Jorstad, I. 1940. Uredinales of Northern Norway. Skr. utg. av. Det. Norske Vindensk.-Akad. i Oslo. I. Mat.-Naturv. Klasse. No. 6. 145p.

Manion, P.D. 1991. Tree Disease Concepts. 2nd edition. Prentice-Hall. 402 p.

McCracken, A.R. and M. Dawson. 1992. Clonal Response in Salix to Melampsora Rusts in Short Rotation Coppice Plantations. Eur. J. For. Path. 22: 19-28.

Pinon, J. 1992. Vaiability in the Genus Populus in Sensitivity to Melampsora Rusts. Silvae Genetica 41: 25-34.

Savile, D.G.O. 1953. Short-season Adaptations in the Rust Fungi. Mycologia 45: 75-87.

Savile, D.B.O. 1973. Rusts That Pass Import Inspection. Can. Plant Dis. Surv., Vol. 53, No. 2. pp 105-106.

Sinclair, W.A., H.H. Lyon and W.T. Johnson. 1987. Diseases of Trees and Shrubs. Cornell University Press. 574 p.

Verwijst, T. 1990. Clonal Differences in the Structure of a Mixed Stand of Salix viminalis in Response to Melampsora and Frost. Can. J. For. Res. 20: 602-605.

Yohem, K.H., G.B. Cummins, and R.L. Gilbertson. 1985. Revised List and Host Index of Arizona Rust Fungi. Micotaxon, Vol. 22, No. 2. pp 451-468.

Ziller, W.G. 1974. The Tree Rusts of Western Canada. Canadian Forestry Service Publication No. 1329, Department of the Environment. 272 p.

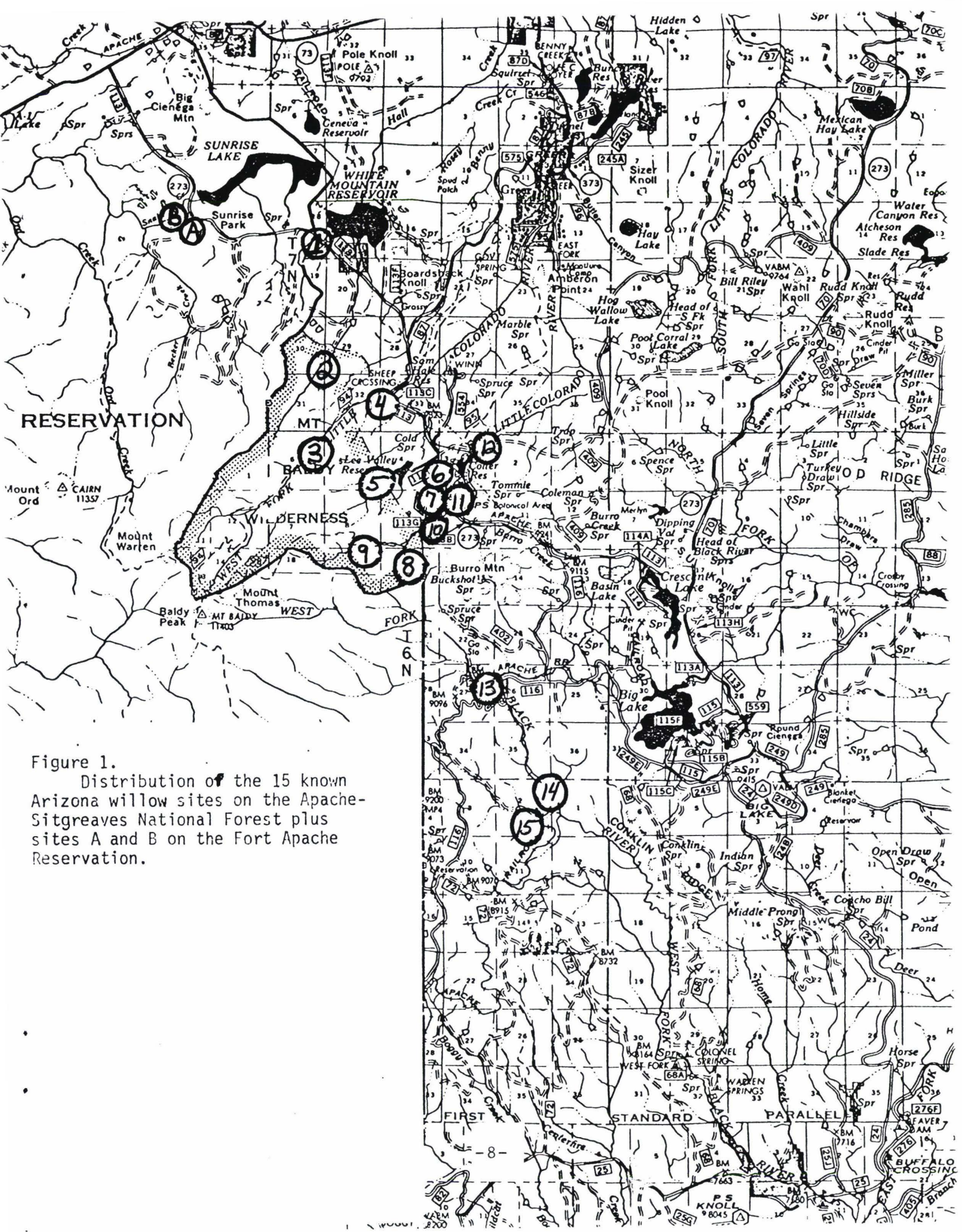
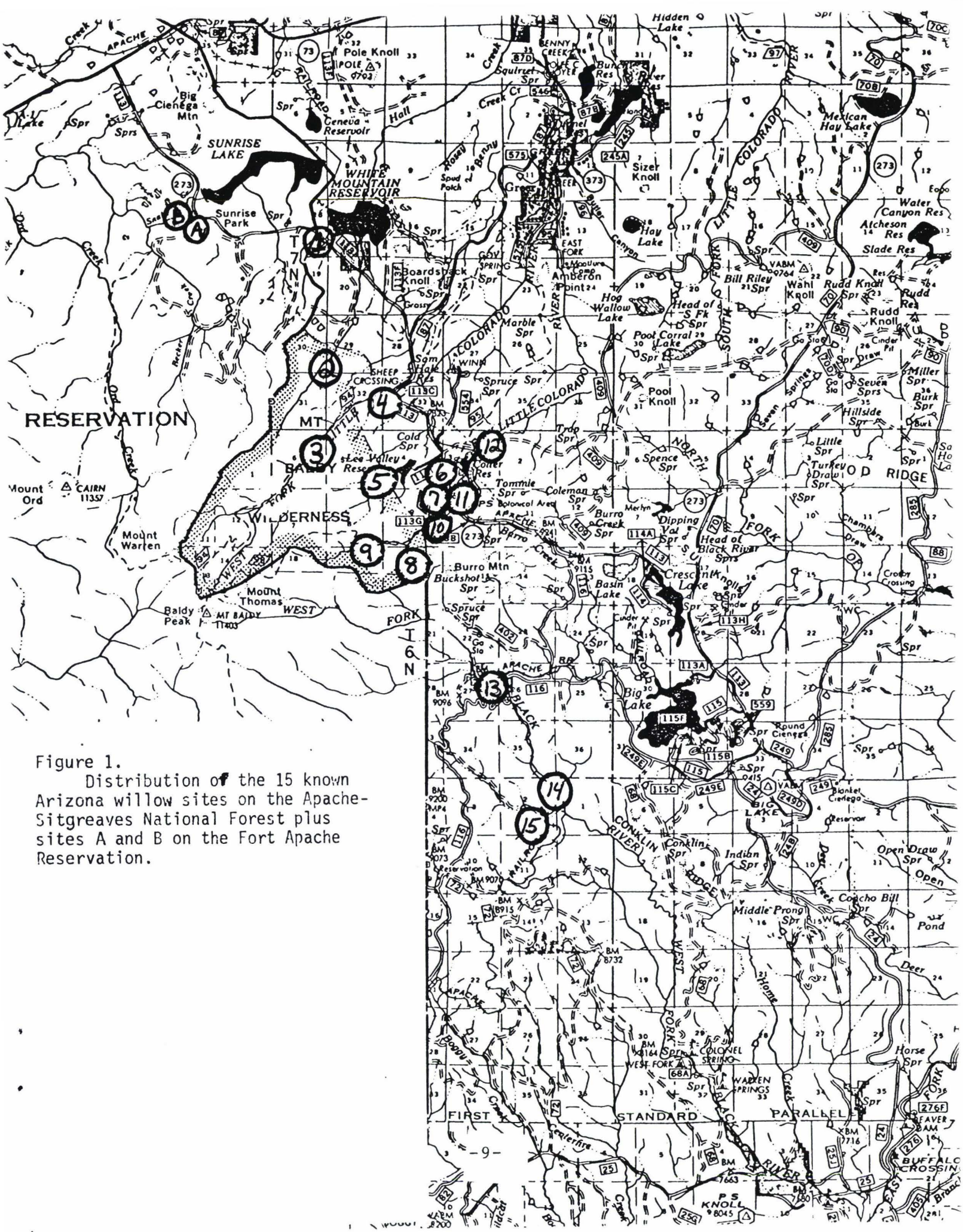


Figure 1.
Distribution of the 15 known Arizona willow sites on the Apache-Sitgreaves National Forest plus sites A and B on the Fort Apache Reservation.



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